Sound Power and Vector Sound Intensity

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I. Introduction

In this laboratory exercise you will use the B&K Sound Intensity Probe Type 3545 with Remote Control Unit ZH 0354 along with the B&K Real-Time Frequency Analyzer Type 2133 to map out the normal component of the vector sound intensity produced by a Dirt Devil® Can Vac™. This lab will familiarize you with the use of an intensity probe, as well as the displays used to analyze intensity data. The intensity maps you will obtain will yield information about the sound radiation and sound energy flow from a common noise source.

II. Background Reading

A sound intensity probe measures sound pressure at two points simultaneously. Given the spacing between the microphones, the approximate sound pressure gradient may be obtained, allowing a determination of the velocity in a given direction. From the pressure and velocity information, the component of the vector intensity in the specified direction may be obtained. A two point approximation of the sound pressure gradient is valid as long as the microphone spacing is small compared to a wavelength of the sound being measured. For ½-inch microphones separated by 12-mm, the upper frequency limit is about 5 kHz. Some very useful additional background information, including several examples of vector sound intensity measurements, may be found in the text ***Noise Control: Measurement, Analysis, and Control of Sound and Vibration*** by Wilson [see sections 1.10, pp.28-34, and 3.12, pp. 121-128]. It is strongly recommended that you read this material before performing the lab exercise, as this text provides a very good introduction to the use of an intensity probe, and shows many examples different ways of displaying sound intensity information. Methods for determining the sound power radiated by an acoustic source, using vector sound intensity measurements are discussed on pages 128-138 of Wilson. In addition, appended at the end of this lab write-up is Chapter 14 from the manual for the B&K Real-Time Frequency Analyzer Type 2133. This chapter discusses an application of this analyzer with the B&K Sound Intensity Probe for measuring sound intensity, and provides a useful familiarization with the intensity probe and analyzer settings for measuring intensity.

III. Setup, Procedure and Analysis

A. Frequency Analyzer and Intensity Probe

This subsection will help you set up the B&K analyzer for intensity measurements, and become familiar with the intensity probe and intensity display format.

- Assemble the Intensity Probe with ½-inch microphones and 12-mm spacing (microphones and spacing should already be ready). Pay attention to how the intensity probe is stored so that you can put it away properly when you are finished.
- Plug the Intensity Probe into the intensity probe input of the B&K frequency analyzer. This input uses both channels, one for each microphone.
- Power up the frequency analyzer, and start it in its default state: <Reset><9>:.
- Set up the analyzer for taking intensity measurements and familiarize yourself with the intensity probe and analyzer display.
- The best procedure for this would be to follow the steps and diagrams in sections 14.1 through 14.3 of the B&K manual pages included at the end of this write-up.

B. Frequency Spectrum for the Noise Source

This subsection will help you identify the major frequency components of the noise generated by the vacuum cleaner.

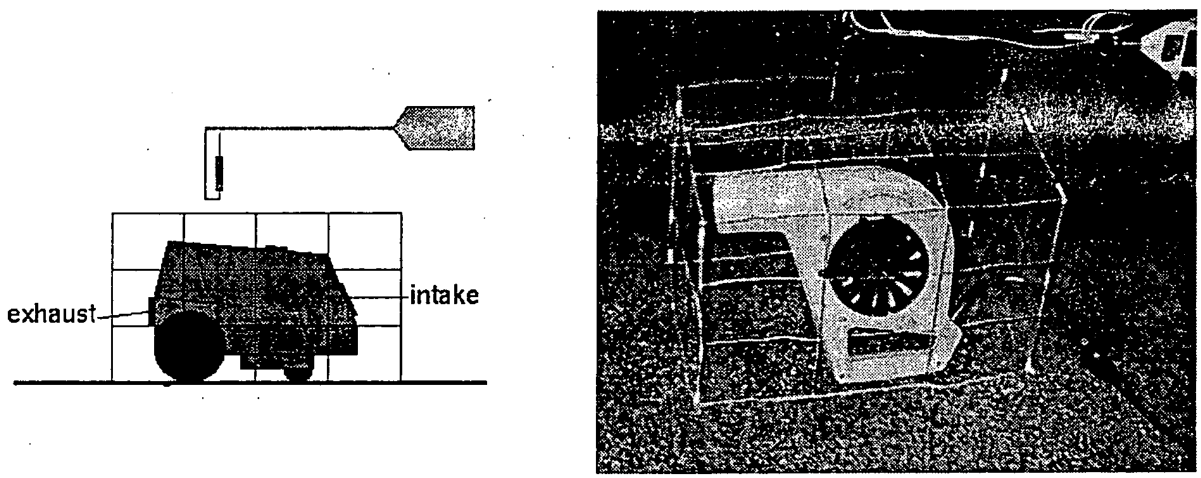
- Connect the Radio Shack Sound Level Meter (or the B&K microphone with charge preamp) to Channel 1 of the HP FFT analyzer. Power up, and set the display for power spectrum --- Display [Meas Data] [F1] "Channel 1" --- [F3] "Power Spectrum Channel 1".
- Adjust the upper limit of the frequency range to around 3000 Hz. --- Measurement [Freq] [F1] "Span" --- use [Uparrow] and [Downarrow] keys on keypad to set frequency span.
- Turn on the vacuum cleaner.
- Measure the frequency spectrum of the noise generated by the vacuum cleaner with the sound level meter or microphone. You may wish to measure the spectrum at several locations, or to take an average (use more than 10 samples in the average) for different locations.
- Use the cursor (marker) to identify any prominent peaks present in the frequency spectrum. These are frequencies about which you will focus your intensity measurements.
- Included at the end of this write-up is an example frequency spectrum for this vacuum cleaner, with some of the major frequencies identified, as well as a waterfall plot obtained by moving a microphone over the surface of the vacuum. This may help you identify some of the major frequency components.
- Identify the 1/3-Octave bands which contain each of these frequency components.

- Save the frequency spectrum to an ASCII file on disk (this file can then be imported into a spreadsheet and plotted later). If you can obtain a plot of the frequency spectrum, then include it with your report.

C. Vacuum and Grid

In order to study the noise produced by a source, we define one or more imaginary surfaces near the source, and then define a grid on each surface. The vector sound intensity is then measured at each grid element. You will measure the normal component of the sound intensity on five (5) surfaces surrounding the source. These surfaces and grids are defined by the wire mesh which is placed over the vacuum. Measurements will be made at the center of each rectangle.

- You will need a scheme for numbering the surfaces and the measurement locations in order to analyze your data later.
- Make a table containing the surfaces and measurement locations, the 1/3-octave bands which contain important frequency components, and the measured sound intensity.



Using wire grid and intensity probe to meausure vector sound intensity: (left) DirtDevil vacuum, (right) leaf blower

D. Measuring the Sound Intensity

- If the B&K frequency analyzer is not set up for intensity measurements, then follow the steps from Chapter 14 of the manual to set up the analyzer.
- Turn on the vacuum cleaner.
- Hold the intensity probe so that the axis on which the microphones lie is perpendicular to the grid rectangle for each measurement location. Hold the probe so that the spacing between microphones is at the center of each rectangle.
- Start a measurement --- press the [Start] key. When the intensity spectrum settles, stop the measurement. Record the intensity levels for each the 1/3-octave bands

containing important frequency components. This will take some teamwork. Be sure to let each person participate in each part of the process.
- Move to the next measurement location and repeat.

E. Analysis

- Plot the normal sound intensity for each 1/3-octave band you recorded on each of the 5 surfaces. The specific choice of plot is up to you (mesh line diagram, contour plot, bar graph, etc.). The examples in Wilson may give you ideas on how to present your data.
- Do your intensity maps yield any information about the directionality of sound energy flow from the vacuum at various frequencies?
- If you are ambitious, measure the area of one of the grid rectangles, and calculate the sound power radiated by the vacuum for one or more of the 1/3-octave bands by summing the intensity over the surface using Equation (3.13.2) of Wilson.
- How does this radiated power compare to the power radiated by a simple source in an infinite baffle, at the same frequency?

IV. References

1. C. E. Wilson, *Noise Control: Measurement, Analysis, and Control of Sound and Vibration*, (Krieger Publishing Co., Malabar, FL, 1994).

2. Manual for the B&K Real-Time Frequency Analyzer Type 2133.

V. Sample Student Data

This laboratory exercise has been used very successfully in a rather popular senior level course, "PHYS-580/ME-530, Acoustics, Noise, and Vibration," which serves as an elective for Mechanical Engineering, Electrical Engineering, and Applied Physics majors at GMI Engineering & Management Institute. Students measured the the noise produced by a Dirt Devil® Can Vac™.